Distribution of Benthic Infaunal Communities in the Vicinity of Point Conception, California

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Abstract - Between 1982-1984, soft-bottom infaunal benthic assemblages were investigated along the shelf and slopes of the Santa Maria and Santa Barbara Basins, near Pt. Conception, California. These efforts were part of a long-term study to determine possible impacts of oil and gas developments. Data analysis delineated five communities whose distribution varied with depth and location along the coast. These spatial trends corresponded better with overlying dissolved oxygen (DO) values and sediment grain size, rather than with other environmental factors. Evaluation of data from this and other subtidal studies along the west coast of North America indicates that dissolved oxygen levels below 4 mg/l appear to have an important effect on regulating the distribution of infaunal communities.

Introduction

Pt. Conception (Fig. 1) is recognized as a biogeographic boundary (Brusca & Wallerstein 1979) or transition zone (Newman 1979) for many intertidal and shallow-water marine organisms between the cold and warm temperate regions along the west coast of North America. Comparable information regarding deeper benthic species and communities is less definitive, since previous studies have focused on one region or the other, rather than across the boundary zone (SMC 1986).

Proposed development of oil and gas resources in the Santa Maria and Santa Barbara Basins, situated respectively north and east of Pt. Conception (Fig. 1), has required a comprehensive, quantitative survey to assess potential impacts on shelf, slope and basin infaunal communities. This long-term investigation provides an opportunity to examine the distribution of the deeper benthic species and communities in the two regions.

The purpose of this initial field study (termed Phase I) was to characterize the benthic habitat, both physically and biologically, in the Santa Maria and Santa Barbara Basin areas in order to provide a basis for subsequent, long-term monitoring during Phases II and III. This paper presents some of
the results of Phase I and compares the distribution of infaunal communities in and between the two areas with corresponding communities' distribution. Preliminary interpretation of some of this data has been provided in Smith & co-author's (1988).

The mean levels of the physical and chemical sediment measurements, as well as community parameters from the two basins, were compared using analysis of variance (ANOVA). The community parameters included number of species, total abundance and the Shannon-Wiener species diversity index (H; Pielou 1969).

Species abundance data from the 1.0 mm screen in the first replicate at each station were used in the community analysis. Spatial community patterns were studied using ordination and cluster analyses. The ordination technique utilized was local nonmetric multidimensional scaling (Prentice 1977), which was based on the Bray-Curtis dissimilarity index, followed by the step-across procedure (Williamson 1978). The species abundance values were transformed by a square root and standardized by the species mean for values greater than zero. Species occurring in fewer than four stations were not used in the computations. The flexible clustering method was used during cluster analysis, with the flexible coefficient beta set at the usual value of -0.25 (Clifford & Stephenson 1975). The dissimilarity values used in the cluster analysis of the stations were the distances between the stations in the ordination space; dissimilarities used in the cluster analysis of the species were the distances between the weighted average positions of the respective species in the ordination space.

Additional details on the ordination and cluster analysis methods are found in SAIC (1986) and Smith & co-author's (1988).

Ordination analysis displays the samples as points in a multidimensional space. The distances between the points in the space are proportional to the dissimilarity of the communities found in the corresponding samples. Samples that contain similar communities will be closer together in the ordination space than samples that contain very dissimilar communities.

Community differences are largely caused by environmental differences and the dimensions (axes) of the ordination space are usually correlated with environmental gradients. To form hypotheses as to which environmental gradients might be causing observed community differences, the ordination axis scores (coordinates of the points on the axes) were used as dependent variables in multiple regression analyses; the environmental measurements (depth, chemical and sediment parameters) were in turn used as independent variables. To simplify the analysis, the all-subsets independent variable selection procedure was utilized (SAS PROC RSQUARE, SAS 1985).

Cluster analysis was used to form groups of stations that contained similar benthic communities. The relationships between the stations and species were examined with a two-way matrix. In this matrix the rows and columns are rearranged to fit the order in the cluster analysis dendrograms of the species and the stations, respectively (Kikkawa 1968; Clifford & Stephenson 1975; Smith & Greene 1976). The rearrangement of rows and columns places similar stations and species in adjacent rows and columns, which makes it easy to see patterns of species among stations.

To save space, the two-way coincidence table is presented in a summarized form with the percentages of each species group within each station group indicated with symbols.

Results

Analysis of the physical and hydrographic characteristics of the two basins indicates variability within and between basins. Bathymetrically the Santa Maria Basin has a wider shelf that drops down to slope depths even greater than that sampled at 1,100 m (Fig. 1). This basin includes a sea valley (at slope depths below 600 m) situated between shallower shelf depths closer to shore and the relatively shallow Santa Lucia Bank located further offshore. South of the sea valley, off Pt. Arguello, the shelf is narrower. The slope here includes a series of shallow subtidal tributaries leading into deeper submarine canyons. This basin, filled with sediments and lacking a surrounding sill to trap water, is a geographic rather than a hydrographic basin. In contrast, the smaller Santa Barbara Basin, situated between the mainland and...
several of the northern Channel Islands, includes a sill at 475 m off Pt. Conception and is relatively shallow, reaching maximum depths of 620 m.

The grain size distribution of the sediments in the two basins was similar (Fig. 3). Analysis of mean grain size indicates that sands were found closer to the mainland, as well as farther north, at shallower depths off the Santa Lucia Bank and along the northern Channel Islands. Mean grain size was smaller (silt) at intermediate distances offshore, extending south and then east from the sea valley in the Santa Maria Basin, into the floor of the Santa Barbara Basin.

The percent of organic carbon associated with the sediments in the two basins correlated with depth ($r^2 = 0.67$) and several grain size parameters, including mean phi ($r^2 = 0.65$) and percent clay ($r^2 = 0.62$). High organic carbon values were found in both the northern portion of the Santa Maria sea valley and along the floor of the Santa Barbara Basin (Fig. 3). Lower values were found in both the northern portion and along the floor of the Santa Barbara Basin compared with 500 m in the Santa Maria Basin.

In the Santa Barbara Channel, dissolved oxygen values from a second study, done at 574 m during July 1970 in the Santa Barbara Basin, also were examined (Sholkovitz & Gieskes 1971). Since these latter values agreed with the CalCOFI results, shallower depths, data from the two sources were combined to provide a comparison of basins at comparable depths. Values in the Santa Maria Basin ranged from 6.90 mg/l on the surface to 0.5 at 500 m (Fig. 4), and were on the average 0.4 mg/l shallower in the Santa Barbara Basin than in the Santa Maria Basin.

in the Santa Barbara Channel ranged from 17.2°C on the surface to 6.0°C at 500 m. On the average, temperatures were 0.5°C significantly higher (P < 0.05) than in the Santa Maria Basin. Salinities in the Santa Barbara Channel ranged from 33.42% on the surface to 34.29 at 500 m. On the average, salinities were 0.1% higher than in the Santa Barbara Basin.

Dissolved oxygen values were also examined over the same 28 yr period but only for the seasonal minima in July. These readings (Lynn et al. 1982) were obtained from the surface in both basins, but only to 300 m in the Santa Barbara Basin compared with 500 m in the Santa Marina Basin.
Biological Communities: Sample processing resulted in the identification of 996 taxa, dominated by polychaetes (434), crustaceans (288), mollusks (154) and other groups (120). The deletion of taxa not identified to species and those occurring in less than four of the samples resulted in the delineation of 179 species used in the community analyses (Table 2).

Results of cluster analysis indicate the presence of five station groupings and six species groupings (Fig. 5). These groupings are summarized in a two-way contingency matrix to show species groups in association with station groups. The organisms associated with each species group are provided in Table 2.

An aerial map indicates communities are distributed generally along an onshore-offshore gradient (Fig. 2). A cross sectional diagram of the two basins with depth, viewed from offshore, shows the relationship of the communities more clearly (Fig. 6). The dashed lines show the level of similarity among these communities. The major break among communities occurred at 500 m and separated both the Santa Maria deep slope community and the Santa Barbara Basin community from other communities located at shallower depths. The shallow shelf community occupied outer shelf depths (30-200 m) and extended along the coast through both basins. A sub-shelf community occupied comparable depths north and east of the sub-shelf community. Depths greater than 500 m were inhabited by a lower slope community in the Santa Maria Basin and an ecologically similar basin community east of Pt. Conception.

Ordination analysis provides an ecological view of the relationships among all stations comprising the five communities (Fig. 7). The distribution of communities in multidimensional space is plotted along the first two axes which displayed the greatest amount of ecological variability. Situated along the left side of axis 1 was the shelf community which occupied the shallowest depths. At the opposite end of axis 1 was the most ecologically distant community, the basin community at the bottom of the Santa Barbara Basin (though not occurring at the greatest depths surveyed). The distribution of samples and communities along axis 2 does not show any apparent geographic or bathymetric pattern.

A summary of biological characteristics of each community is presented in Table 3. Shallower communities and communities with higher dissolved oxygen had higher richness (number of species), total abundance of organisms (number of specimens), and diversity levels (Shannon-Wiener).

Regulating Factors: Regression analyses (Table 4) showed that depth was most highly correlated with the community variation expressed along ordination axis 1 ($r^2 = 0.77$). Weaker correlations were found for organic carbon ($r^2 = 0.53$) and percent clay ($r^2 = 0.26$).
The correlation between axis 1 and depth is somewhat consistent with the distribution of station groups in Figure 7, where the shallowest shelf group is found at the negative end of axis 1 and deeper slope and basin groups are found toward the positive end. However, the fact that the basin group at the far right is not found at the deepest water depths indicates that some factor other than depth may be influencing the community changes corresponding with this axis. Dissolved oxygen (DO), which was not measured as part of this field study, appears to follow this gradient along axis 1. DO values are highest in the shallower shelf groups at the negative end of axis 1 and lowest in the Santa Barbara Basin community at the extreme positive end of the axis.

The relationship between DO and infaunal communities also can be seen in a plot of communities along an oxygen and a depth gradient of the two basins (Fig. 8). The shallowest community, located on the shelf, occupied the highest DO levels. The sub-shelf and upper slope communities occupied similar depths in the Santa Maria Basin and overlapped somewhat in DO level. The lower slope community in the Santa Maria Basin occupied the greatest depths surveyed but not the lowest DO levels. Finally, the basin community in the Santa Barbara Basin, located at the extreme end of the ecological gradient along axis 1 (Fig. 7), was associated with the lowest DO levels but not the greatest depths (Fig. 8).

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Axis 2, representing secondary environmental factor(s), corresponded somewhat with sediment parameters of sand and clay (Table 4). Communities located higher up along axis 2 were found either nearshore (shelf) or further offshore along the slopes of the Santa Maria Basin where sand was more abundant (Fig. 3). Communities lower down along axis 2 were located in areas such as the Santa Barbara Basin, where sand was less abundant.

Discussion

Physical Factors: The Santa Maria Basin is deeper, has both a sea valley and a system of submarine canyons, and, therefore, bathymetrically more complex than the Santa Barbara Basin in the vicinity of Pt. Conception. The percent sand was greatest in shallow, shelf waters in both basins and relatively shallow waters located offshore.

The organic content of the sediments varied more within than between basins. Values were highest in the sea valley of the Santa Maria Basin and the floor of the Santa Barbara Basin. This distribution is attributed to finer particle size with greater surface area for attachment. One area at sea valley depths, between Pt. Sal and Pt. Arguello, had low values of organics.

Biological Communities: The distribution of infaunal communities along the shelf, slope and basins varied primarily with depth as reported in southern California by Thompson & Jones (1987). A secondary spatial trend involved changes alongshore, particularly off Pt. Conception.

<table>
<thead>
<tr>
<th>Community</th>
<th>Depth (m)</th>
<th>DO</th>
<th>Species</th>
<th>Specimens</th>
<th>Diversity</th>
<th>Characteristic Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Shelf</td>
<td>30-175</td>
<td>2.0</td>
<td>68</td>
<td>236</td>
<td>2.91</td>
<td>Amphiodia urtica</td>
</tr>
<tr>
<td>2. Sub-shelf</td>
<td>200-350</td>
<td>1.3</td>
<td>32</td>
<td>81</td>
<td>2.90</td>
<td>Spinifex berkeleyorum</td>
</tr>
<tr>
<td>3. Upper Slope</td>
<td>300-400</td>
<td>0.7</td>
<td>23</td>
<td>57</td>
<td>2.83</td>
<td>Pisaster bartoni</td>
</tr>
<tr>
<td>4. Lower Slope</td>
<td>900-1100</td>
<td>0.2</td>
<td>74</td>
<td>2.62</td>
<td></td>
<td>Nuculana conceptionis</td>
</tr>
<tr>
<td>5. Basin</td>
<td>500-600</td>
<td>0.1</td>
<td>10</td>
<td>27</td>
<td>1.69</td>
<td>Mitrella permodesta</td>
</tr>
</tbody>
</table>
were above 4 mg/l, however, when DO levels dropped below 4 mg/l, species and total abundance values in each community decreased. Rosenberg (1977) noted that when the DO levels dropped below 4 mg/l, a level in other studies has been reported to contain enzymes adapted to low oxygen, high sulfide environments (Felbeck et al. 1981). Increased surface area for respiration has been reported in echinoids (Thompson pers. comm.) and polychaetes (Montagne pers. comm.) in areas of lower DO levels, regardless of depth. Davis (1977) reported that gamete development in the polychaete Nereis diversicolor is inhibited at oxygen levels below 4 mg/l. Thompson (1982) reported that at deep, low oxygen depths off southern California, the number of sub-surface deposit feeders decreased. This trend could be due to lower oxygen values within the sediments. Ordination axis 2 corresponded best with two grain size parameters, percentage of sand and clay. These are two parameters that have traditionally been thought to regulate benthic communities. The importance of sand may be due to its greater permeability for water and therefore oxygen exchange (Weston 1988). Organic carbon, another factor which has been noted to regulate benthic communities, did not correspond strongly along either axis. In articles published since the submittal of this paper, there is further evidence that oxygen levels correspond strongly with the distribution of infaunal benthic communities along the west coast of North America. This paper, as well as other studies along the west coast of North America, provides substantive evidence that even at levels as high as 4 mg/l, oxygen levels may be more important than previously thought.

### Acknowledgments

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### Literature Cited


**Table 4. Results of multiple regression analysis for ordination axes 1 and 2 showing r^2 values for one and two value functions.**

<table>
<thead>
<tr>
<th>No. Variables in Model</th>
<th>r^2</th>
<th>Independent Variables in Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axis 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.79</td>
<td>Water Depth</td>
</tr>
<tr>
<td>2</td>
<td>0.51</td>
<td>Organic Carbon</td>
</tr>
<tr>
<td>3</td>
<td>0.26</td>
<td>Percent Clay</td>
</tr>
<tr>
<td>4</td>
<td>0.19</td>
<td>Total Hydrocarbons</td>
</tr>
<tr>
<td>5</td>
<td>0.17</td>
<td>Silt 25</td>
</tr>
<tr>
<td>6</td>
<td>0.11</td>
<td>Total Aromatics</td>
</tr>
<tr>
<td>7</td>
<td>0.10</td>
<td>Grain Size</td>
</tr>
<tr>
<td>8</td>
<td>0.82</td>
<td>Water Depth + Percent Clay</td>
</tr>
</tbody>
</table>

| Axis 2                 |          |                                 |
| 1                      | 0.18     | Sand                            |
| 2                      | 0.17     | Mode Grain Size                 |
| 3                      | 0.13     | Total Hydrocarbons              |
| 4                      | 0.09     | Total Alkanes                   |
| 5                      | 0.08     | Mean Grain Size                 |
| 6                      | 0.07     | Oil Pollution Index             |
| 7                      | 0.26     | Sand + Clay                     |


Davis, W.R. and D.J. Reish. 1975. The effect of reduced dissolved oxygen concentration on the growth and production of oocytes in the


